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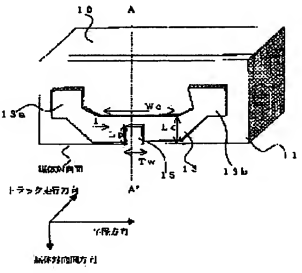
(54) PERPENDICULAR MAGNETIC RECORDING HEAD, AND PERPENDICULAR MAGNETIC RECORDING DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To prevent the destruction of the recording information of a perpendicular recording medium caused by residual magnetization by stably controlling the residual magnetization of a recording magnetic pole in a perpendicular magnetic recording head for narrow track recording.
SOLUTION: This perpendicular magnetic recording head for recording information in the perpendicular magnetic recording medium is provided with a recording magnetic pole for recording the information in the perpendicular magnetic recording medium, a conductor disposed near the recording magnetic pole to excite the same, and a return yoke disposed at a specified space from the recording magnetic pole. The recording magnetic pole is not directly connected to the return yoke, and the pole length of the recording magnetic pole is shorter than the length of the conductor in a direction opposite to the medium.



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CLAIMS

[Claim(s)]
[Claim 1] In the vertical-magnetic-recording head which records information on a vertical-magnetic-recording medium The conductor which approaches the record magnetic pole which records information on said vertical-magnetic-recording medium, and said record magnetic pole, and is arranged, and excites said record magnetic pole, The vertical-magnetic-recording head which it has the return yoke arranged at the predetermined spacing to said record magnetic pole, and said record magnetic pole does not couple directly with said return yoke, and is characterized by the pole length of said record magnetic pole being shorter than the medium opposed face lay length of said conductor.
[Claim 2] The maximum of an exciting current which flows the number of said conductors arranged by approaching said record magnetic pole to N and said conductor Imax, When magnitude of the anisotropy field of R and said record magnetic pole is set [the truck transit lay length of said conductor / Dc and the medium opposed face lay length of said conductor] to Hk for the distance between Lc, said conductor, and said record magnetic pole, Said record magnetic pole and said conductor are following relational-expression Hk<NxImax/2 (Dc+Lc+2R).
The vertical-magnetic-recording head according to claim 1 characterized by being satisfied.
[Claim 3] Said conductor is a vertical-magnetic-recording head according to claim 1 or 2 characterized by being arranged in said direction of a medium opposed face in the location which retreated rather than the arrangement location of said record magnetic pole.
[Claim 4] Said record magnetic pole is a vertical-magnetic-recording head according to claim 1 to 3 to which magnitude Hd of the static magnetic field which produces the spontaneous magnetization of said record magnetic pole in the interior at the time of making it saturated to a longitudinal direction is characterized by being smaller than the anisotropy field Hk of said record magnetic pole.
[Claim 5] Said record magnetic pole is the following relational expression [several 2], when the configuration was a strip of paper-like, and Tw and pole length are set to Lp and it sets [the magnitude of the saturation magnetic flux of said record magnetic pole / the magnitude of B and an anisotropy field] thickness to Dp for Hk and recording track width of face.

$$Hk > 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right)B$$

The vertical-magnetic-recording head according to claim 1 to 3 characterized by being satisfied.
[Claim 6] A vertical-magnetic-recording medium and the driving means which supports and drives [rotation] said vertical-magnetic-recording medium, The vertical-magnetic-recording head which records information to said vertical-magnetic-recording medium, It is vertical-magnetic-recording equipment possessing the support means which supports said vertical-magnetic-recording head free [migration] to said vertical-magnetic-recording medium. Said vertical-magnetic-recording medium The record magnetic pole of a recording layer and a soft magnetism backing layer by which it has a bilayer at least and said vertical-magnetic-recording head records information on said vertical-magnetic-recording medium, The conductor which approaches said record magnetic pole, and is arranged, and excites said record magnetic pole, The vertical-magnetic-recording regenerative apparatus which it has the return yoke arranged at the predetermined spacing to said record magnetic

pole, and said record magnetic pole does not couple directly with said return yoke, and is characterized by the pole length of said record magnetic pole being shorter than the medium opposed face lay length of said conductor.
[Claim 7] The maximum of an exciting current which flows the number of said conductors arranged by approaching said record magnetic pole to N and said conductor Imax, When magnitude of the anisotropy field of R and said record magnetic pole is set [the truck transit lay length of said conductor / Dc and the medium opposed face lay length of said conductor] to Hk for the distance between Lc, said conductor, and said record magnetic pole, Said record magnetic pole and said conductor are following relational-expression Hk<NxImax/2 (Dc+Lc+2R).
Vertical-magnetic-recording equipment according to claim 6 by which it is satisfied characterized.
[Claim 8] Said conductor is vertical-magnetic-recording equipment according to claim 6 or 7 characterized by being arranged in said direction of a medium opposed face in the location which retreated rather than the arrangement location of said record magnetic pole.
[Claim 9] Said record magnetic pole is the following relational expression [several 2], when the configuration was a strip of paper-like, and Tw and pole length are set to Lp and it sets [the magnitude of the saturation magnetic flux of said record magnetic pole / the magnitude of B and an anisotropy field] thickness to Dp for Hk and recording track width of face.

$$Hk > 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right) B$$

Vertical-magnetic-recording equipment according to claim 6 to 8 characterized by being satisfied.
[Claim 10] Said support means is vertical-magnetic-recording equipment according to claim 6 to 9 characterized by supporting said vertical-magnetic-recording head so that it may become shorter than the distance of said record magnetic pole and said return yoke about the distance of said record magnetic pole and soft magnetism backing layer of said vertical-magnetic-recording medium at the time of the information record actuation to said vertical-magnetic-recording medium.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the vertical-magnetic-recording equipment using the vertical-magnetic-recording head and this which are applied to a vertical-magnetic-recording technique.
[0002]
[Description of the Prior Art] In recent years, in the field of magnetic recording, such as a magnetic recording medium, recording density is increasing by leaps and bounds, and the vertical magnetic recording which can maintain magnetization at stability with high recording density attracts attention in connection with this. More various things than before are proposed also about the single magnetic pole head which is one of the vertical-magnetic-recording heads used for this vertical magnetic recording, for example, what aimed at the excitation effectiveness at the time of record of a record magnetic pole and an improvement of a high-frequency property is indicated in JP,11-110717,A by giving the configuration which carried out contiguity arrangement of the thin film coil for excitation near the thin film record magnetic pole tip.
[0003]
[Problem(s) to be Solved by the Invention] However, although narrow-track-izing of the record magnetic pole of a single magnetic pole head and thin film-ization will progress further in connection with the further densification of recording density from now on, when realizing thin film-ization of the record magnetic pole of a single magnetic pole head, the big problem of the control to the residual magnetization of not only the problem about the increase in efficiency of the excitation at the time of record of a record magnetic pole but the record magnetic pole at the time of un-recording arises. This is the problem that the residual magnetization of a record magnetic pole will generate a disturbance field to a vertical-magnetic-recording medium toward the direction of a medium opposed face of a magnetic-recording medium at the time of current un-impressing, when the configuration of the record magnetic pole of a single magnetic pole head becomes long and slender in the direction of a medium opposed face (direction which intersects perpendicularly with a medium opposed face (ABS side), and goes to a medium opposed face).
[0004] On the other hand, with the single magnetic pole head of the conventional technique, where the thin film coil for excitation which had thickness so that a record current could be borne is inserted in between, the structure to which direct coupling of a record magnetic pole and the return yoke was carried out is given. For this reason, since three-dimension-[a configuration] complication and expanding-izing of a record magnetic pole progress as narrow track-ization of the record magnetic pole of a single magnetic pole head progresses, the residual magnetization of a record magnetic pole tends to turn to the direction of a medium opposed face at the time of current un-impressing, and it has possibility (recording information is eliminated or other information is written in) of destroying recording information of a vertical-magnetic-recording medium.
[0005] So, in this invention, it aims at providing stability with a controllable vertical-magnetic-recording head and vertical-magnetic-recording equipment for the residual magnetization of the record magnetic pole in the vertical-magnetic-recording head for narrow track record to which narrow track-ization progressed in connection with the densification of recording density.
[0006]

[Means for Solving the Problem] In the vertical-magnetic-recording head with which the vertical-magnetic-recording head of this invention records information on a vertical-magnetic-recording medium The conductor which approaches the record magnetic pole which records information on said vertical-magnetic-recording medium, and said record magnetic pole, and is arranged, and excites said record magnetic pole, It has the return yoke arranged at the predetermined spacing to said record magnetic pole, and said record magnetic pole does not couple directly with said return yoke, and it is characterized by the pole length of said record magnetic pole being shorter than the medium opposed face lay length of said conductor.

[0007] Moreover, the driving means to which the vertical-magnetic-recording regenerative apparatus of this invention supports and drives [rotation] a vertical-magnetic-recording medium and said vertical-magnetic-recording medium, The vertical-magnetic-recording head which records information to said vertical-magnetic-recording medium, It is vertical-magnetic-recording equipment possessing the support means which supports said vertical-magnetic-recording head free [migration] to said vertical-magnetic-recording medium. Said vertical-magnetic-recording medium The record magnetic pole of a recording layer and a soft magnetism backing layer by which it has a bilayer at least and said vertical-magnetic-recording head records information on said vertical-magnetic-recording medium, The conductor which approaches said record magnetic pole, and is arranged, and excites said record magnetic pole, It has the return yoke arranged at the predetermined spacing to said record magnetic pole, and said record magnetic pole does not couple directly with said return yoke, and it is characterized by the pole length of said record magnetic pole being shorter than the medium opposed face lay length of said conductor.

[0008] It is possible to prevent destruction of the vertical-magnetic-recording medium under the effect of a leakage field by the above-mentioned configuration, since generating of the strong leakage field by the residual magnetization of the record magnetic pole at the time of un-recording can be controlled. Moreover, it is possible to realize the vertical-magnetic-recording head and vertical-magnetic-recording equipment suitable for the magnetic recording in the RF in which it has a dominant property that the component of the direction of a medium opposed face of magnetization of the whole record magnetic pole increases by magnetization rotation from the time of un-recording at the time of record.

[0009]

[Embodiment of the Invention] (Vertical-magnetic-recording head structure) With reference to a drawing, the gestalt of operation of this invention is explained hereafter.

[0010] The outline structure of the single magnetic pole head which is a vertical-magnetic-recording head of this invention is shown in drawing 1 . Drawing 2 is the cross-section schematic diagram of the direction of A-A' of the single magnetic pole head shown in drawing 1 .

[0011] As for the single magnetic pole head shown in drawing 1 and drawing 2 , laminating film production of the return yoke 11 of a soft magnetic material, an insulating layer 12, the thin film conductor 13 for excitation, an insulating layer 14, and the record magnetic pole 15 of a soft magnetic material is carried out on the substrate 10. In addition, in drawing 1 , illustration of an insulating layer 12 and an insulating layer 14 is omitted. The exciting current I for having combined electrically 13a and 13b which are the both ends of the thin film conductor 13 with the conductor which is not illustrated, and exciting the record magnetic pole 15 from the conductor concerned to both ends 13a and 13b is passed. The record magnetic pole 15 does not couple directly the single magnetic pole head of this invention with the return yoke 11, and the pole length Lp of the record magnetic pole 15 has a configuration shorter than the medium opposed face lay length Lc of the thin film conductor 13 so that drawing 1 and drawing 2 may show.

[0012] When the record magnetic pole 15 has the configuration coupled directly with the return yoke 11, the pole length Lp of the record magnetic pole 15 becomes long inevitably rather than the medium opposed face lay length Lc of the thin film conductor 13. For this reason, when making large the cross section which intersects perpendicularly in the direction of a current of the thin film conductor 13, or to consider as the structure which carried out the laminating of the thin film conductor 13 of two or more sheets, it is necessary to lengthen more the pole length Lp of the record magnetic pole 15. On the other hand, with the single magnetic pole head of this invention, by considering as the configuration which does not couple the record magnetic pole 15 directly with the

thin film conductor 13, it prevents lengthening extremely the pole length Lp of the record magnetic pole 15, and it is made into the configuration to which the ratio (aspect ratio) of the pole length Lp of the record magnetic pole 15 and the recording track width of face Tw does not become extremely large by this.

[0013] Moreover, as shown by a thing, and drawing 5 and drawing 6 which prepare two or more thin film conductors as shown by drawing 3 and drawing 4 as a configuration of a single magnetic pole head in addition to what is shown in drawing 1 and drawing 2 , a thin film conductor may be prepared in the both sides of a record magnetic pole.

[0014] The single magnetic pole head shown in drawing 3 and drawing 4 has the configuration which added further the insulating layer 16 and the thin film conductor 17 between the thin film conductor 13 and the insulating layer 14 to the single magnetic pole head shown in drawing 1 and drawing 2 . About the same configuration as drawing 1 and the single magnetic pole head of drawing 2 , the same sign is given into drawing 3 and drawing 4 . However, in drawing 3 , illustration of insulating layers 12, 14, and 16 is omitted. Moreover, drawing 4 is the cross-section schematic diagram of the direction of A-A' of the single magnetic pole head shown in drawing 3 . In addition, although the number of sheets of the thin film conductor which approaches a record magnetic pole and is arranged is made into two sheets with the single magnetic pole head shown in this drawing 3 and drawing 4 , the number of sheets of a thin film conductor is good also not only as this but three sheets or more.

[0015] Moreover, the single magnetic pole head shown in drawing 5 and drawing 6 has the configuration which added the insulating layer 18 and the thin film conductor 19 further on the record magnetic pole 15 to the single magnetic pole head shown in drawing 1 and drawing 2 . About the same configuration as drawing 1 and the single magnetic pole head of drawing 2 , the same sign is given into drawing 5 and drawing 6 . However, in drawing 5 , illustration of insulating layers 12, 14, and 18 is omitted. Moreover, the exciting current I which passes the direction of exciting-current I' passed to the thin film conductor 19 to the thin film conductor 13 is hard flow at this time. Drawing 6 is the cross-section schematic diagram of the direction of A-A' of the single magnetic pole head shown in drawing 5 . Furthermore, he arranges the thin film conductors 13 and 19 in the location (location which retreated from the medium opposed face in the direction of a medium opposed face) distant from the medium opposed face of a single magnetic pole head, and is trying to detach distance with the vertical-magnetic-recording medium which counters the thin film conductors 13 and 19 with this single magnetic pole head so that drawing 5 and drawing 6 may show. This is for preventing the field generated from the thin film conductors 13 and 19 reaching a vertical-magnetic-recording medium directly, and destroying the recording information of the vertical-magnetic-recording medium concerned.

[0016] In addition, although it approached and one thin film conductor is arranged to each both ends of a record magnetic pole with the single magnetic pole head shown in drawing 5 and drawing 6 , you may make it two or more number of sheets of the thin film conductor arranged to these both ends prepare not only one sheet but both of the sides.

[0017] Moreover, the configuration which arranges a thin film conductor in the location distant from the medium opposed face of a single magnetic pole head may be used for the single magnetic pole head shown not only in drawing 5 and the single magnetic pole head of 6 but in drawing 1 thru/or drawing 4 .

(Configuration of a record magnetic pole) Next, as mentioned above, how to bend extremely greatly explains the aspect ratio of the record magnetic pole 15 about a good reason. When performing use by high track density, and the recording track width of face Tw of a record magnetic pole is 0.5 micrometers or less, with the thin film single magnetic pole head which has the structure of a conventional type as shown in drawing 14 or drawing 15 , an aspect ratio becomes very large. The thin film single magnetic pole head of the example 1 of a comparison shown in drawing 14 has structure which has seldom narrowed down the recording track width of face Tw of the record magnetic pole 71, and where the conductor 72 for excitation is inserted in between, it is directly joined to the return yoke 73.

[0018] Even while in the case of such structure the pole length Lp of the record magnetic pole 71 becomes very long and is not impressing the exciting current to the conductor 72 for excitation, in

order to avoid a configuration anti-field, in the record magnetic pole 71, it becomes easy to produce residual magnetization in the direction of a medium opposed face. In the condition that residual magnetization is suitable in the direction of a medium opposed face in the record magnetic pole 71, the recording information of a vertical-magnetic-recording medium will be destroyed by the field generated from the residual magnetization of the record magnetic pole 71 only by the record magnetic pole 71 running a vertical-magnetic-recording medium top.

[0019] The thin film single magnetic pole head of the example 2 of a comparison shown in drawing 15 serves as the configuration where the record magnetic pole 81 narrowed down the recording track width of face Tw at the tip, and it has the structure which this record magnetic pole 81 joined to the return yoke 83 directly where the conductor 82 for excitation is inserted in between. If the location 84 of narrowing down of the record magnetic pole 81 is close brought at a tip too much, field distribution of the width-of-recording-track Tw direction of the magnetic signal at the time of record will become broadcloth by the interaction of the side face of the narrowing-down location 84 of the record magnetic pole 81, and the backing layer of a vertical-magnetic-recording medium. Conversely, by narrow track width of face, if the narrowing-down location 84 of the record magnetic pole 81 is separated from a tip, since narrowing down is too tight, the problem that magnetic flux cannot flow easily to the tip of the record magnetic pole 81 will arise.

[0020] Many of troubles of the examples 1 and 2 of these comparisons originate in a configuration limit of a record magnetic pole. Generally, it is known that it will be easy to turn to the soft magnetism thin film used as the ingredient of a record magnetic pole in the pole length Lp direction in which the easy axis in a record magnetic pole met the configuration, so that the aspect ratio in the configuration is large.

[0021] Change of the easy axis according to this aspect ratio is explained below. In order to show change of the magnetic-domain condition when changing the aspect ratio of a soft magnetism thin film, the situation of the magnetic-domain condition of the record magnetic pole using the soft magnetism thin film which has an aspect ratio which is different in drawing 7 thru/or drawing 9 is shown, respectively.

[0022] Drawing 7 shows typically the magnetic-domain condition of the residual magnetization when setting an aspect ratio to 4:1 in the record magnetic pole using the thin film which consisted of soft magnetic materials, such as a permalloy.

[0023] When the record magnetic pole gives the magnetization anisotropy to the longitudinal direction (it sets to drawing and is the direction of either of the direction of the right, and the direction of the right to the left from the left), the magnetic-domain condition takes closure domain structure, but by the record magnetic pole which set the aspect ratio to 4:1, also after residual magnetization has remained, in the exterior of the direction of a medium opposed face of a record magnetic pole, a stray magnetic field is hardly produced. If it is the record magnetic pole which has such a magnetic-domain condition, even if it turns the tip of the direction of a medium opposed face to a magnetic-recording medium at the time of un-recording, the recording information of a vertical-magnetic-recording medium will not be destroyed by the leakage field produced by residual magnetization. Therefore, it becomes possible to add a record field to a vertical-magnetic-recording medium by the record magnetic pole at the time of record, only when an exciting current is impressed to the conductor for excitation.

[0024] Drawing 8 shows typically the magnetic-domain condition of the residual magnetization in the record magnetic pole for which the aspect ratio used the thin film of 6:1. Since the anti-field by the longwise configuration of what has taken closure domain structure with the whole thin film of a record magnetic pole is large, the magnetic-domain area which met in the direction of a medium opposed face of a record magnetic pole is large. For this reason, a leakage field arises from the tip of the direction of a medium opposed face by the residual magnetization of a record magnetic pole. However, that leakage field is small and, in the case of the record magnetic pole of this aspect ratio, it is thought that possibility of saying that the recording information of a vertical-magnetic-recording medium is destroyed by that leakage field at the time of un-recording is low.

[0025] Drawing 9 shows typically the magnetic-domain condition of the residual magnetization in the record magnetic pole for which the aspect ratio used the thin film of 20:1. Since the internal field by the configuration of the record magnetic pole will be strengthened even if it is going to turn the

magnetization anisotropy of film original of a record magnetic pole to a longitudinal direction as shown by drawing 9 , will be suitable of all residual magnetization in the direction of a medium opposed face. In a record magnetic pole with the magnetic-domain condition of this residual magnetization, even if it is at the time of not recording, when the tip of that direction of a medium opposed face is turned to a magnetic-recording medium, the recording information of a magnetic-recording medium will be destroyed by the strong leakage field produced by residual magnetization.
[0026] Thus, in order to control destruction of the recording information of the vertical-magnetic-recording medium by the residual magnetization of the record magnetic pole at the time of un-recording, it is necessary to use what has the value of an aspect ratio small as a configuration of a record magnetic pole.
[0027] Next, when a field is impressed to drawing 7 and the record magnetic pole using the thin film of drawing 8 in the direction of a medium opposed face, it explains how the magnetic-domain condition changes.
[0028] Drawing 10 shows typically the magnetic-domain condition when the aspect ratio shown in drawing 7 impresses a field in the direction of a medium opposed face to the record magnetic pole using the thin film of 4:1. Drawing 11 shows typically change of a magnetic-domain condition when the aspect ratio shown in drawing 8 impresses a field in the direction of a medium opposed face to the record magnetic pole using the thin film of 6:1.
[0029] As shown in drawing 10 , since the magnetic-domain area in which magnetization has turned to the longitudinal direction is large, when a field is impressed, by the aspect ratio's record magnetic pole using the thin film of 4:1, it becomes dominant that the component of the direction of a medium opposed face of magnetization of the whole record magnetic pole increases because lateral magnetization carries out magnetization rotation in the direction of a medium opposed face. In addition, although the domain wall displacement that the magnetic-domain area in which magnetization is suitable in the direction of a medium opposed face and this direction becomes large is produced while the magnetic-domain area in which magnetization has turned to the direction of a medium opposed face and hard flow in this case becomes small, as compared with magnetization rotation, that ratio of the increment in the direction component of a medium opposed face of the magnetization by this domain wall displacement is low, and there is little effectiveness.
[0030] On the other hand, in the aspect ratio's of drawing 10 record magnetic pole using the thin film of 6:1, the magnetic-domain area in which magnetization is suitable in the direction of a medium opposed face is large, and there is little magnetic-domain area in which magnetization has turned to the longitudinal direction to this from the first. For this reason, the direction of a medium opposed face has a ratio larger [the effectiveness by the domain wall displacement to which the magnetic-domain area in which magnetization is suitable in the direction of a medium opposed face and this direction becomes large] than the effectiveness by lateral magnetization carrying out magnetization rotation of the increment in the direction component of a medium opposed face in the direction of a medium opposed face while the magnetic-domain area in which magnetization has turned to hard flow becomes small. For this reason, this domain wall displacement becomes the dominant factor of the increment in the direction component of a medium opposed face.
[0031] Since it is generally known that the magnetization rotation will be performed at a high speed rather than domain wall displacement, when the application to the magnetic recording which is a RF is taken into consideration, drawing 6 and the record magnetic pole using the thin film of the aspect ratio 4:1 of drawing 10 can say that it has the structure suitable for the record magnetic pole which performs magnetic recording in a RF rather than drawing 7 and the record magnetic pole using the thin film of the aspect ratio 6:1 of drawing 11 .
[0032] Furthermore, although the aspect ratio of the record magnetic pole suitable for the magnetic recording in a RF changes also with the class of the soft magnetic materials, or thickness of a thin film, in order to consider as optimal magnetic-domain condition like drawing 7 , it should just serve as a value with the larger magnitude Hk of the anisotropy field to the longitudinal direction of a record magnetic pole than the static magnetic field Hd produced inside the film of the record magnetic pole when magnetizing and saturating a record magnetic pole in a longitudinal direction uniformly. A record magnetic pole takes the value the static magnetic field Hd which is produced inside the film in the case of-like [strip-of-paper] is indicated to be by the formula 1 like drawing 7 .

(Formula 1)
[0033]
[Equation 1]

$$Hd = 8 \arctan \left(\frac{DpLp}{Tw \sqrt{Dp^2 + Tw^2 + Lp^2}} \right) B$$

[0034] Here, Tw and thickness are set to Dp and saturation magnetic flux density is set [the pole length of a record magnetic pole] to B for Lp and recording track width of face.
[0035] Therefore, what is necessary is just to make it the anisotropy field Hk of a record magnetic pole have [a static magnetic field Hd] a configuration with which a formula 2 is filled as a record magnetic pole in order for what is necessary to be just to become large also in a twist. (Formula 2)
[0036]
[Equation 2]

$$Hk > 8 \arctan \left(\frac{DpLp}{Tw \sqrt{Dp^2 + Tw^2 + Lp^2}} \right) B$$

[0037] (Distance of a record magnetic pole and a thin film conductor) Next, the distance of the record magnetic pole of the single magnetic pole head of this invention and a thin film conductor is explained.
[0038] With the single magnetic pole head of this invention shown in drawing 1 thru/or drawing 6 , since the record magnetic pole 15 has structure which is not coupled directly with the return yoke 11, the effectiveness on the magnetic circuit by the record magnetic pole 15 and the return yoke 11 falls to some extent. For this reason, in order to make the record magnetic pole 15 generate sufficient magnetization for record, it is necessary to utilize enough the field generated on the front face of the thin film conductor 13 by the record magnetic pole 15. That is, with the thin film conductor 13, in order to make the record magnetic pole 15 whole generate a field uniformly, it is necessary to fully carry out contiguity arrangement of the whole surface of the thin film conductor 13 and the record magnetic pole 15.
[0039] Here, when an exciting current I flows to the thin film conductor 13, the magnetic field strength H generated around the thin film conductor 13 is calculated in approximation. As shown in drawing 1 and drawing 2 , the die length (truck transit lay length) of Lc (it is the same as the medium opposed face lay length Lc of the thin film conductor 13) and width is set to Dc for the die length of the length of a cross section to the direction (it is the same as radial) of exciting-current I of the thin film conductor 13. Moreover, the radius lay length Wc of the thin film conductor 13 presupposes that it is sufficiently long to the recording track width of face Tw of the record magnetic pole 15. If an exciting current I is passed to the thin film conductor 13 at this time, the field H generated in the location which only distance r separated from the thin film conductor 13 will take in approximation the value shown by the formula 3.
(Formula 3)
H=I/2(Lc+Dc+2r)
It is possible to add uniformly the field H excited from the thin film conductor 13 to the whole record magnetic pole 15 with the single magnetic pole head of this invention, since the radius lay length Wc of the thin film conductor 13 is sufficiently longer than the recording track width of face Tw of the record magnetic pole 15. Therefore, when maximum of the exciting current I which flows the distance of the thin film conductor 13 and the record magnetic pole 15 to R and the thin film conductor 13 is set to Imax, the maximum Hmax of a field which joins the record magnetic pole 15 takes the value shown by the formula 4.
(Formula 4)
Hmax=Imax/2(Lc+Dc+2R)
Therefore, in order to strengthen the field added to the record magnetic pole 15, it is necessary to shorten distance R of the thin film conductor 13 and the record magnetic pole 15. Since it is required to add the field of the strength more than the anisotropy field Hk of the record magnetic pole 15 to the whole record magnetic pole 15 in order to saturate the spontaneous magnetization in the record

magnetic pole 15, the distance R of the thin film conductor 13 and the record magnetic pole 15 should just take the value of the range with which a formula 5 is filled.
(Formula 5)
Hk<Imax/2(Lc+Dc+2R)
Although the above is the case where the number of the thin film conductors 13 which carry out contiguity arrangement at the record magnetic pole 15 is one, it is also possible to arrange a thin film conductor on both sides of a record magnetic pole like drawing 5 and 6 in multilayering a thin film conductor like drawing 3 and 4. Here, supposing it sets to N (N> 1) the number of sheets of the thin film conductor which carries out contiguity arrangement at a record magnetic pole and the distance of two or more thin film conductors serves as the ********** same value R to a record magnetic pole, the distance R of a record magnetic pole and two or more thin film conductors should just take the value of the range with which a formula 6 is filled.
(Formula 6)
Hk<NxImax/2 (Lc+Dc+2R)
As explained above, with the single magnetic pole head of this invention shown in drawing 1 thru/or drawing 6 , the record magnetic pole was made into the configuration where the value of an aspect ratio is small, by not carrying out direct coupling of the record magnetic pole to a return yoke, and making the pole length Lp of a record magnetic pole shorter than the medium opposed face lay length Lc of a thin film conductor. Since generating of the strong leakage field by the residual magnetization of the record magnetic pole at the time of un-recording can be controlled by this, it is possible to prevent destruction of the magnetic-recording medium under the effect of a leakage field. Moreover, it is possible to realize the single magnetic pole head to which it will have a dominant property to which that the record magnetic pole of the component of the direction of a medium opposed face of magnetization of the whole record magnetic pole increases by magnetization rotation from the time of un-recording at the time of record, and it was suitable for the magnetic recording in a RF by considering as the small configuration of an aspect ratio.
(Magnetic disk drive) Next, the vertical-magnetic-recording equipment using drawing 1 of this invention thru/or the single magnetic pole head of drawing 6 is explained.
[0040] The general-view Fig. of the vertical-magnetic-recording equipment of this invention is shown in drawing 12 . As shown in drawing 12 , the vertical-magnetic-recording equipment of this invention has top covering which blockades upper limit opening of the case 25 on the rectangle box which carried out opening in the top face, and the case by which ****s to a case 25 with two or more screw threads, and a stop is carried out and which is not illustrated. In a case 25 It considers as the vertical-magnetic-recording medium 21 and the driving means which supports and rotates this vertical-magnetic-recording medium 21. Have the suspension which carried the magnetic head 22 which performs informational record and playback to the ** spindle motor 20 and the vertical-magnetic-recording medium 21, and the magnetic head 22 at the tip, and the vertical-magnetic-recording medium 21 is received in the magnetic head 22. The voice coil motor 26 and the head amplifier circuit 24 which mind the revolving shaft 27 and revolving shaft 27 which are supported for the head actuator 23 and the head actuator 23 which are supported free [migration], enabling free rotation, and rotate and position the head actuator 23 are contained.
[0041] Moreover, the enlarged drawing of the magnetic head 22 of the vertical-magnetic-recording equipment of this invention is shown in drawing 13 . In drawing 13 , the magnetic head 22 has the Records Department 30 and the playback section 40. Among these, the single magnetic pole head of this invention is used for the Records Department 30, and this Records Department 30 consists of a record magnetic pole 15, a thin film conductor 13, a return yoke 11, etc. The Records Department 30 is included in the surfacing slider 50 with the playback section 40, and when this surfacing slider 50 carries out surfacing transit of the vertical-magnetic-recording medium 60 top which rotates at a predetermined rate in a super-low location, the record magnetic pole 15 and the return yoke 11 are carrying out contiguity opposite to magnetic-recording medium 60 front face.
[0042] Moreover, the vertical-magnetic-recording medium 60 is a vertical-magnetic-recording medium set as the record object of the information on the vertical-magnetic-recording equipment of this invention, and the laminating of the protective layer 64 by the perpendicular orientation magnetic-recording layer 63, carbon film, etc. using the soft magnetism backing layer 62 which used

a permalloy, Sendust, CoZrNb, etc. on the substrate 61 using aluminum, tempered glass, etc., a CoCr system alloy, a CoPt system alloy, etc., and the lubricating layer 65 is carried out to order. The soft magnetism backing layer 62 and the perpendicular orientation magnetic-recording layer 63 may have the substrate layer aiming at crystal orientation control etc., respectively.

[0043] Here, in the structural physical relationship of the Records Department 30 of the magnetic head 22, and the magnetic-recording medium 60, the conditions which enable suitable information record to the magnetic-recording medium 60 are explained below.

[0044] As conditions which enable suitable information record to the magnetic-recording medium 60, when distance between S, the record magnetic pole 15, and the return yoke 11 is set to D for the magnetic spacing from the tip of the record magnetic pole 15 to the soft magnetism backing layer 62 of the magnetic-recording medium 60, it is needed that the magnetic spacing S is shorter than distance D. That is, the magnetic spacing S will pass the perpendicular orientation magnetic-recording layer 63 perpendicularly, and the magnetic flux which came out from the tip of the record magnetic pole 15 when shorter than distance D will return to the return yoke 11 via the soft magnetism backing layer 62, and serves as flow of magnetic flux suitable as vertical magnetic recording. Since the magnetic flux which came out from the tip of the record magnetic pole 15 will concentrate in the direction which flows to the return yoke 11 and magnetic flux will hardly flow to the soft magnetism backing layer 62 on the other hand when the direction of distance D has become shorter than the magnetic spacing S, as structural physical relationship of the Records Department 30 of the magnetic head 22, and the magnetic-recording medium 60, it is unsuitable.

[0045] Thus, information record can be performed in a good vertical-magnetic-recording property by performing information record in the physical relationship which the magnetic spacing S from the tip of the record magnetic pole 15 to the soft magnetism backing layer 62 made shorter than the distance D between the record magnetic pole 15 and the return yoke 11.

[0046]

[Effect of the Invention] The record magnetic pole was made into the configuration where the value of an aspect ratio is small, by not carrying out direct coupling of the record magnetic pole to a return yoke in this invention, as explained in full detail above, and making the pole length of a record magnetic pole shorter than the medium opposed face lay length of a thin film conductor. Since generating of the strong leakage field by the residual magnetization of the record magnetic pole at the time of un-recording can be controlled by this, it is possible to prevent destruction of the vertical-magnetic-recording medium under the effect of a leakage field. Moreover, it is possible to realize the vertical-magnetic-recording head and vertical-magnetic-recording equipment with which it was suitable for the magnetic recording in a RF with a dominant property that the component of the direction of a medium opposed face of magnetization of the whole record magnetic pole increases by magnetization rotation from the time of un-recording by making a record magnetic pole into the small configuration of an aspect ratio at the time of record.

[Translation done.]

* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Outline structural drawing of the single magnetic pole head concerning the operation gestalt of this invention.
[Drawing 2] The cross-section schematic diagram of the single magnetic pole head concerning the operation gestalt of this invention.
[Drawing 3] Outline structural drawing of the single magnetic pole head of a configuration of having prepared two or more thin film conductors concerning the operation gestalt of this invention.
[Drawing 4] The cross-section schematic diagram of the single magnetic pole head of a configuration of having prepared two or more thin film conductors concerning the operation gestalt of this invention.
[Drawing 5] Outline structural drawing of the single magnetic pole head of a configuration of having prepared the thin film conductor concerning the operation gestalt of this invention in the both sides of a record magnetic pole.
[Drawing 6] The cross-section schematic diagram of the single magnetic pole head of a configuration of having prepared the thin film conductor concerning the operation gestalt of this invention in the both sides of a record magnetic pole.
[Drawing 7] Drawing in which the aspect ratio showed typically the magnetic-domain condition of the record magnetic pole of the configuration of 4:1.
[Drawing 8] Drawing in which the aspect ratio showed typically the magnetic-domain condition of the record magnetic pole of the configuration of 6:1.
[Drawing 9] Drawing in which the aspect ratio showed typically the magnetic-domain condition of the record magnetic pole of the configuration of 20:1.
[Drawing 10] Drawing having shown typically the magnetic-domain condition when an aspect ratio impresses a field in the direction of a medium opposed face in the record magnetic pole of the configuration of 4:1.
[Drawing 11] Drawing having shown typically the magnetic-domain condition when an aspect ratio impresses a field in the direction of a medium opposed face in the record magnetic pole of the configuration of 6:1.
[Drawing 12] The general-view Fig. of the vertical-magnetic-recording equipment concerning the operation gestalt of this invention.
[Drawing 13] Drawing for explaining the optimal structural physical relationship of the perpendicular magnetic head of vertical-magnetic-recording equipment and the vertical-magnetic-recording medium concerning the operation gestalt of this invention.
[Drawing 14] Outline structural drawing of the thin film single electrode head of the conventional type of the example 1 of a comparison.
[Drawing 15] Outline structural drawing of the thin film single electrode head of the conventional type of the example 2 of a comparison.
[Description of Notations]
10 -- Substrate
11 -- Return yoke
12, 14, 16, 18 -- Insulating layer
13, 17, 19 -- Thin film conductor

15 -- Record magnetic pole
20 -- Spindle motor
21 -- Vertical-magnetic-recording medium
22 -- Magnetic head
23 -- Head actuator
24 -- Head amplifier circuit
25 -- Case
26 -- Voice coil motor
27 -- Revolving shaft
30 -- Records Department
40 -- Playback section
50 -- Surfacing slider
60 -- Vertical-magnetic-recording medium
61 -- Substrate
62 -- Soft magnetism backing layer
63 -- Perpendicular orientation magnetic-recording layer
64 -- Protective layer
65 -- Lubricating layer
71 81 -- Record magnetic pole
72 82 -- Conductor for excitation
73 83 -- Return yoke
84 -- It narrows down and is a location.

[Translation done.]

* NOTICES *

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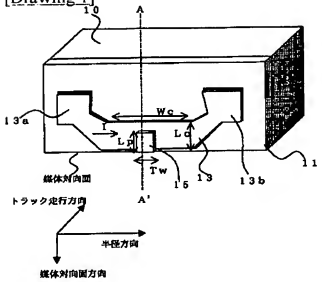
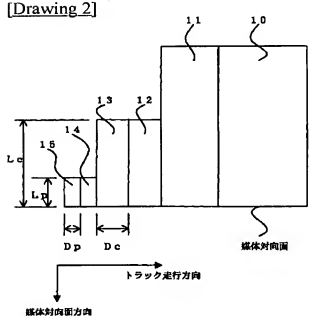
DRAWINGS

[Drawing 1]



[Drawing 2]



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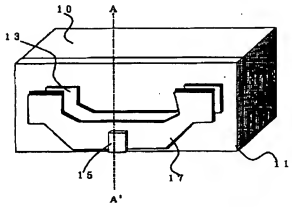

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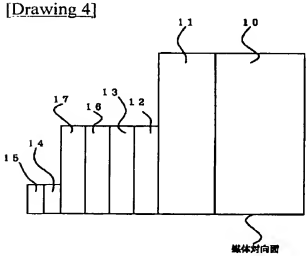

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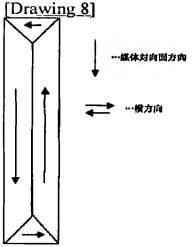
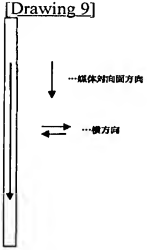
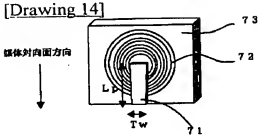


[Drawing 9]



[Drawing 14]



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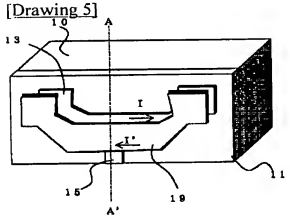

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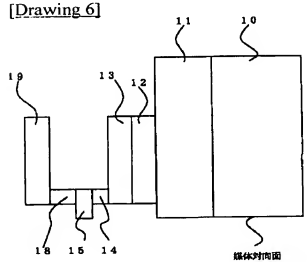

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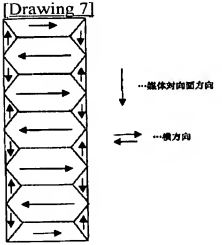
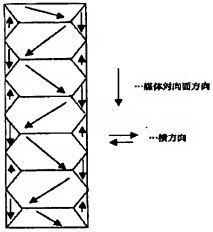
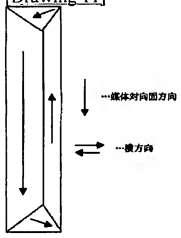


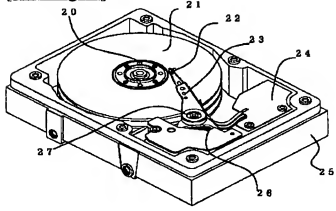
[Drawing 10]



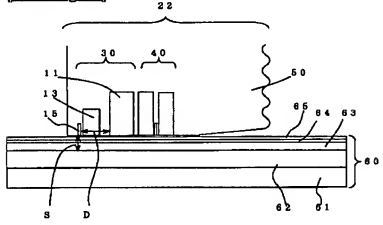
[Drawing 11]



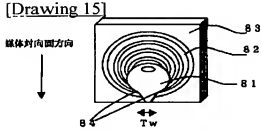
[Drawing 12]



[Drawing 13]



[Drawing 15]



[Translation done.]

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				Ｄ　５Ｄ０３３
				Ｆ
5/667		5/667		

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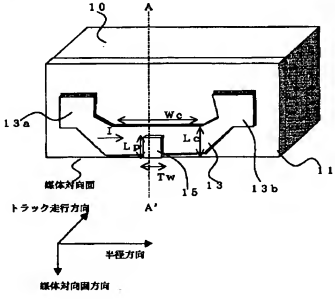
Ｆターム(参考)　5D006 CA03 DA03 DA08 FA09
5D033 AA05 BA07 BA12 BA32

(54)【発明の名称】　垂直磁気記録ヘッド及び垂直磁気記録装置

(57)【要約】
【課題】　狭トラック記録用の垂直磁気記録ヘッドにおいて、記録磁極の残留磁化を安定に制御可能とし、残留磁化による垂直記録媒体の記録情報の破壊を防止する。
【解決手段】　垂直磁気記録媒体に情報の記録を行なう垂直磁気記録ヘッドにおいて、前記垂直磁気記録媒体に情報の記録を行なう記録磁極と、前記記録磁極に近接して配置され且つ前記記録磁極を励磁する導電体と、前記記録磁極に対して所定の間隔にて配置されるリターンヨークとを有し、前記記録磁極が前記リターンヨークと直接結合せず且つ前記記録磁極のポール長が前記導電体の媒体対向面方向の長さよりも短いことを特徴とする。



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【特許請求の範囲】

【請求項１】　垂直磁気記録媒体に情報の記録を行なう垂直磁気記録ヘッドにおいて、

前記垂直磁気記録媒体に情報の記録を行なう記録磁極と、

前記記録磁極に近接して配置され且つ前記記録磁極を励磁する導電体と、

前記記録磁極に対して所定の間隔にて配置されるリターンヨークとを有し、

前記記録磁極が前記リターンヨークと直接結合せず且つ前記記録磁極のポール長が前記導電体の媒体対向面方向の長さよりも短いことを特徴とする垂直磁気記録ヘッド。

【請求項２】　前記記録磁極に近接して配置される前記導電体の数をＮ、前記導電体に流れる励磁電流の最大値をＩｍａｘ、前記導電体のトラック走行方向の長さをＤｃ、前記導電体の媒体対向面方向の長さをＬｃ、前記導電体と前記記録磁極との間の距離をＲ、前記記録磁極の異方性磁界の大きさをＨｋとしたとき、前記記録磁極及び前記導電体が、次の関係式

$$Hk > 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right)B$$

を満足することを特徴とする請求項１乃至３記載の垂直磁気記録ヘッド。

【請求項６】　垂直磁気記録媒体と、前記垂直磁気記録媒体を支持及び回転駆動する駆動手段と、前記垂直磁気記録媒体に対して情報の記録を行なう垂直磁気記録ヘッドと、前記垂直磁気記録媒体に対して前記垂直磁気記録ヘッドを移動自在に支持する支持手段とを具備する垂直磁気記録装置であって、

前記垂直磁気記録媒体は、記録層と軟磁性裏打ち層の少なくとも二層を有し、前記垂直磁気記録ヘッドが、前記垂直磁気記録媒体に情報の記録を行なう記録磁極と、前記記録磁極に近接して配置され且つ前記記録磁極を励磁する導電体と、前記記録磁極に対して所定の間隔にて配置されるリターンヨークとを有し、前記記録磁極が前記リターンヨークと直接結合せず且つ前記記録磁極のポール長が前記導電体の媒体対向面方向の長さよりも短いことを特徴とする垂直磁気記録再生装置。

【請求項７】　前記記録磁極に近接して配置される前記※及び前記導電体が、次の関係式

$$Hk > 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right)B$$

を満足することを特徴とする請求項６乃至８記載の垂直磁気記録装置。

【請求項１０】　前記支持手段は、前記垂直磁気記録媒体への情報記録動作時において、前記記録磁極と前記垂直磁気記録媒体の軟磁性裏打ち層との距離を前記記録磁極と前記リターンヨークとの距離よりも短くなるように前記垂直磁気記録ヘッドを支持することを特徴とする請

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＊＊求項６乃至９記載の垂直磁気記録装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、垂直磁気記録技術に適用される垂直磁気記録ヘッド及びこれを用いた垂直磁気記録装置に関する。

【０００２】

＊　び前記導電体が、次の関係式

Ｈｋ＜Ｎ×Ｉｍａｘ／２（Ｄｃ＋Ｌｃ＋２Ｒ）

を満足することを特徴とする請求項１記載の垂直磁気記録ヘッド。

【請求項３】　前記導電体は、前記媒体対向面方向において、前記記録磁極の配置位置よりも後退した位置に配置されていることを特徴とする請求項１又は２記載の垂直磁気記録ヘッド。

【請求項４】　前記記録磁極は、前記記録磁極の自発磁化を横方向へ飽和させた時の内部に生じる静磁界の大きさＨｄが、前記記録磁極の異方性磁界Ｈｋよりも小さいことを特徴とする請求項１乃至３記載の垂直磁気記録ヘッド。

【請求項５】　前記記録磁極は、その形状が短冊状であり、且つ、前記記録磁極の飽和磁束の大きさをＢ、異方性磁界の大きさをＨｋ、記録トラック幅をＴｗ、ポール長をＬｐ、厚さをＤｐとしたとき、次の関係式

【数２】

※導電体の数をＮ、前記導電体に流れる励磁電流の最大値をＩｍａｘ、前記導電体のトラック走行方向の長さをＤｃ、前記導電体の媒体対向面方向の長さをＬｃ、前記導電体と前記記録磁極との間の距離をＲ、前記記録磁極の異方性磁界の大きさをＨｋとしたとき、前記記録磁極及び前記導電体が、次の関係式

Ｈｋ＜Ｎ×Ｉｍａｘ／２（Ｄｃ＋Ｌｃ＋２Ｒ）

を満足すること特徴とする請求項６記載の垂直磁気記録装置。

【請求項８】　前記導電体は、前記媒体対向面方向において、前記記録磁極の配置位置よりも後退した位置に配置されていることを特徴とする請求項６又は７記載の垂直磁気記録装置。

【請求項９】　前記記録磁極は、その形状が短冊状であり、且つ、前記記録磁極の飽和磁束の大きさをＢ、異方性磁界の大きさをＨｋ、記録トラック幅をＴｗ、ポール長をＬｐ、厚さをＤｐとしたとき、次の関係式

【数２】

$$Hk > 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right)B$$

【従来の技術】近年、磁気記録装置等の磁気記録の分野では、記録密度が飛躍的に増加しており、これに伴い、高記録密度にて安定に磁化を保つことが可能な垂直磁気記録方式が注目されている。この垂直磁気記録方式に用いられる垂直磁気記録ヘッドの一つである単磁極ヘッドについても、従来より様々なものが提案されており、例えば、特開平１１－１１０７１７号公報では、励磁用の薄膜コイルを薄膜記録磁極先端付近に近接配置した構成を持たせることにより、記録磁極の記録時の励磁効率、及び、高周波数特性の改善を図ったものが開示されている。

【０００３】

【発明が解決しようとする課題】しかしながら、今後、記録密度のさらなる高密度化に伴い、単磁極ヘッドの記録磁極の狭トラック化、薄膜化がいっそう進むこととなるが、単磁極ヘッドの記録磁極の薄膜化を実現する上では、記録磁極の記録時の励磁の効率化に関する問題のみならず、非記録時における記録磁極の残留磁化に対する制御という大きな問題が生じる。これは、単磁極ヘッドの記録磁極の形状が媒体対向面方向（媒体対向面（ＡＢＳ面）に直交し且つ媒体対向面に向かう方向）に細長くなると、電流非印加時においても記録磁極の残留磁化が磁気記録媒体の媒体対向面方向へ向いてしまい、垂直磁気記録媒体に対して外乱磁界を発生させてしまうという問題である。

【０００４】一方、従来技術の単磁極ヘッドでは、記録電流に耐えうるように厚みを持った励磁用の薄膜コイルを間にはさんだ状態で、記録磁極とリターンヨークとを直接結合させた構造を持たせている。このため、単磁極ヘッドの記録磁極の狭トラック化が進むにつれ、記録磁極の形状が３次元的な複雑化及び伸長化が進むことから、電流非印加時に記録磁極の残留磁化が媒体対向面方向を向きやすく、垂直磁気記録媒体の記録情報を破壊（記録情報を消去したり、他の情報を書き込む等）してしまう可能性を持っている。

【０００５】そこで、本発明では、記録密度の高密度化に伴い狭トラック化が進んだ狭トラック記録用の垂直磁気記録ヘッドにおいて、その記録磁極の残留磁化を安定に制御可能な垂直磁気記録ヘッド及び垂直磁気記録装置を提供することを目的とする。

【０００６】

【課題を解決するための手段】本発明の垂直磁気記録ヘッドは、垂直磁気記録媒体に情報の記録を行なう垂直磁気記録ヘッドにおいて、前記垂直磁気記録媒体に情報の記録を行なう記録磁極と、前記記録磁極に近接して配置され且つ前記記録磁極を励磁する導電体と、前記記録磁極に対して所定の間隔にて配置されるリターンヨークとを有し、前記記録磁極が前記リターンヨークと直接結合せず且つ前記記録磁極のポール長が前記導電体の媒体対向面方向の長さよりも短いことを特徴とする。

【０００７】また、本発明の垂直磁気記録再生装置は、垂直磁気記録媒体と、前記垂直磁気記録媒体を支持及び回転駆動する駆動手段と、前記垂直磁気記録媒体に対して情報の記録を行なう垂直磁気記録ヘッドと、前記垂直磁気記録媒体に対して前記垂直磁気記録ヘッドを移動自在に支持する支持手段とを具備する垂直磁気記録装置であって、前記垂直磁気記録媒体は、記録層と軟磁性裏打ち層の少なくとも二層を有し、前記垂直磁気記録ヘッドが、前記垂直磁気記録媒体に情報の記録を行なう記録磁極と、前記記録磁極に近接して配置され且つ前記記録磁極を励磁する導電体と、前記記録磁極に対して所定の間隔にて配置されるリターンヨークとを有し、前記記録磁極が前記リターンヨークと直接結合せず且つ前記記録磁極のポール長が前記導電体の媒体対向面方向の長さよりも短いことを特徴とする。

【０００８】上記構成により、非記録時の記録磁極の残留磁化による強い漏洩磁界の発生を抑制可能であるため、漏洩磁界の影響による垂直磁気記録媒体の破壊を防止することが可能である。また、非記録時から記録時において磁化回転により記録磁極全体の磁化の媒体対向面方向の成分が増えていくのが支配的な特性を有する高周波での磁気記録に適した垂直磁気記録ヘッド及び垂直磁気記録装置を実現することが可能である。

【０００９】

【発明の実施の形態】（垂直磁気記録ヘッド構造）以下、図面を参照して本発明の実施の形態について説明する。

【００１０】図１に、本発明の垂直磁気記録ヘッドである単磁極ヘッドの概略構造を示している。図２は、図１に示される単磁極ヘッドのＡ－Ａ’方向の断面概略図である。

【００１１】図１及び図２に示す単磁極ヘッドは、基板１０上に、軟磁性体のリターンヨーク１１、絶縁層１２、励磁用の薄膜導電体１３、絶縁層１４、軟磁性体の記録磁極１５が積層製膜されている。なお、図１では、絶縁層１２及び絶縁層１４の図示を省略している。薄膜導電体１３の両端部である１３ａと１３ｂは、図示せぬ導体に電気的に結合しており当該導体から両端部１３ａ、１３ｂに記録磁極１５の励磁を行うための励磁電流Ｉが流される。図１及び図２から分かるように、本発明の単磁極ヘッドは、リターンヨーク１１と記録磁極１５が直接結合せず、且つ、記録磁極１５のポール長Ｌｐが薄膜導電体１３の媒体対向面方向の長さＬｃよりも短い構成を持っている。

【００１２】記録磁極１５がリターンヨーク１１に直接結合する構成を持つ場合、記録磁極１５のポール長Ｌｐは、薄膜導電体１３の媒体対向面方向の長さＬｃよりも必然的に長くなる。このため、薄膜導電体１３の電流方向に直交する断面積を広くする場合や、複数枚の薄膜導電体１３を積層した構造とする場合には、記録磁極１５

のポール長Ｌｐをより長くする必要がある。これに対して、本発明の単磁極ヘッドでは、記録磁極１５を薄膜導電体１３に直接結合しない構成とすることで、記録磁極１５のポール長Ｌｐを極端に長くすることを防ぎ、これによって、記録磁極１５のポール長Ｌｐと記録トラック幅Ｔｗとの比率（アスペクト比）が極端に大きくならない形状としている。

【００１３】また、単磁極ヘッドの構成としては、図１と図２に示すもの以外に、図３と図４で示されるように薄膜導電体を複数枚設けるものや、図５と図６で示されるように薄膜導電体を記録磁極の両側に設けたものであっても良い。

【００１４】図３及び図４に示す単磁極ヘッドは、図１及び図２に示す単磁極ヘッドに対して、薄膜導電体１３と絶縁層１４の間に絶縁層１６と薄膜導電体１７を更に追加した構成を有している。図３及び図４中において、図１及び図２の単磁極ヘッドと同じ構成については、同じ符号を付与している。但し、図３では、絶縁層１２、１４、１６の図示を省略している。また、図４は、図３に示される単磁極ヘッドのＡ－Ａ’方向の断面概略図である。なお、この図３及び図４に示される単磁極ヘッドでは、記録磁極に近接して配置する薄膜導電体の枚数を２枚としているが、薄膜導電体の枚数はこれに限らず３枚以上としても良い。

【００１５】また、図５及び図６に示す単磁極ヘッドは、図１及び図２に示す単磁極ヘッドに対して、記録磁極１５の上にさらに絶縁層１８と薄膜導電体１９を追加した構成を有している。図５及び図６中において、図１及び図２の単磁極ヘッドと同じ構成については、同じ符号を付与している。但し、図５では、絶縁層１２、１４、１８の図示を省略している。また、このとき、薄膜導電体１９に流す励磁電流Ｉ’の方向は、薄膜導電体１３に流す励磁電流Ｉとは逆方向である。図６は、図５に示される単磁極ヘッドのＡ－Ａ’方向の断面概略図である。さらに、図５及び図６から分かるように、この単磁極ヘッドでは、薄膜導電体１３、１９を、単磁極ヘッドの媒体対向面から離れた位置（媒体対向面方向において媒体対向面から後退した位置）に配置し、薄膜導電体１３、１９に対向する垂直磁気記録媒体との距離を離すようにしている。これは、薄膜導電体１３及び１９から発生する磁界が、垂直磁気記録媒体に直接到達し、当該垂直磁気記録媒体の記録情報を破壊することを防ぐためである。

【００１６】なお、図５及び図６に示す単磁極ヘッドでは、記録磁極の両端に１枚ずつ薄膜導電体を近接して配置しているが、この両端に配置する薄膜導電体の枚数は１枚に限らず、どちらの側も２枚以上設けるようにしても良い。

【００１７】また、薄膜導電体を単磁極ヘッドの媒体対向面から離れた位置に配置する構成は、図５、６の単磁極ヘッドに限らず、図１乃至図４に示す単磁極ヘッドに用いても良い。

（記録磁極の形状）次に、上述したように記録磁極１５のアスペクト比を極端に大きくしない方が良い理由について説明する。高トラック密度での利用を行う上で、記録磁極の記録トラック幅Ｔｗが０．５μｍ以下となってきた場合、図１４や図１５に示すような従来型の構造を有する薄膜単磁極ヘッドでは、アスペクト比が非常に大きくなる。図１４に示される比較例１の薄膜単磁極ヘッドは、記録磁極７１の記録トラック幅Ｔｗをあまり絞り込んでない構造となっており、励磁用導電体７２を間にはさんだ状態でリターンヨーク７３と直接接合している。

【００１８】このような構造の場合、記録磁極７１のポール長Ｌｐが非常に長くなり、励磁用導電体７２に励磁電流を印加していない時でも、記録磁極７１では、形状反磁界を避けるために媒体対向面方向に残留磁化を生じやすくなってしまう。記録磁極７１において残留磁化が媒体対向面方向に向いている状態では、記録磁極７１が垂直磁気記録媒体上を走行するだけで、記録磁極７１の残留磁化から発生する磁界によって、垂直磁気記録媒体の記録情報が破壊されてしまう。

【００１９】図１５に示される比較例２の薄膜単磁極ヘッドは、記録磁極８１が記録トラック幅Ｔｗを先端で絞り込んだ形状となっており、この記録磁極８１が、励磁用導電体８２を間にはさんだ状態でリターンヨーク８３と直接接合した構造を有している。記録磁極８１の絞り込みの位置８４を先端に近づけ過ぎると、記録磁極８１の絞り込み位置８４の側面と垂直磁気記録媒体の裏打ち層との相互作用により、記録時の磁気信号のトラック幅Ｔｗ方向の磁界分布がブロードになってしまう。逆に記録磁極８１の絞り込み位置８４を先端から離すと、狭トラック幅では絞り込みがきつすぎるため、記録磁極８１の先端まで磁束が流れにくいという問題が生じる。

【００２０】これら比較例１及び２の問題点の多くは、記録磁極の形状制限に起因するものである。一般に、記録磁極の材料となる軟磁性薄膜はその形状におけるアスペクト比が大きい程、記録磁極における磁化容易軸がその形状に沿ったポール長Ｌｐ方向に向きやすいことが知られている。

【００２１】このアスペクト比に応じた磁化容易軸の変化について、次に説明する。軟磁性薄膜のアスペクト比を変化させたときの磁区状態の変化を示すために、図７乃至図９に、異なるアスペクト比を有する軟磁性薄膜を用いた記録磁極の磁区状態の様子をそれぞれ示している。

【００２２】図７は、例えば、パーマロイなどの軟磁性材料で構成された薄膜を用いた記録磁極において、アスペクト比を４：１としたときの残留磁化の磁区状態を模式的に示している。

【００２３】記録磁極は、磁化異方性を横方向（図において、左から右の方向と、右から左の方向のどちらかの方向）につけている場合、その磁区状態が還流磁区構造をとるが、アスペクト比を４：１とした記録磁極では、残留磁化の残った状態でも、記録磁極の媒体対向面方向の外部には漏洩磁場はほとんど生じない。このような磁区状態を有する記録磁極であれば、非記録時に、磁気記録媒体にその媒体対向面方向の先端を向けても残留磁化によって生じる漏洩磁界によって垂直磁気記録媒体の記録情報が破壊されることはない。したがって、記録時に、励磁用導電体に励磁電流を印加したときにのみ、記録磁極によって、垂直磁気記録媒体に対して記録磁界を加えることが可能となる。

【００２４】図８は、アスペクト比が６：１の薄膜を用いた記録磁極における残留磁化の磁区状態を模式的に示している。記録磁極の薄膜全体で還流磁区構造をとっているものの、その縦長の形状による反磁界が大きいため、記録磁極の媒体対向面方向に沿った磁区面積が大きくなっている。このため、記録磁極の残留磁化によって媒体対向面方向の先端から漏洩磁界が生じる。但し、その漏洩磁界は小さく、このアスペクト比の記録磁極の場合、非記録時にその漏洩磁界により垂直磁気記録媒体の記録情報を破壊するという可能性は低いと考えられる。

【００２５】図９は、アスペクト比が２０：１の薄膜を用いた記録磁極における残留磁化の磁区状態を模式的に示している。図９で示されているように、記録磁極の膜本来の磁化異方性を横方向へ向けようとしても、その記録磁極の形状による内部磁界が強められてしまうため、残留磁化が全て媒体対向面方向に向いた状態になってしまう。この残留磁化の磁区状態を持った記録磁極では、非記録時であっても、その媒体対向面方向の先端を磁気記録媒体に向けると、残留磁化により生じる強い漏洩磁界により磁気記録媒体の記録情報を破壊してしまうことになる。

【００２６】このように、非記録時の記録磁極の残留磁化による垂直磁気記録媒体の記録情報の破壊を抑制するためには、記録磁極の形状としてアスペクト比の値の小さいものを用いる必要がある。

【００２７】次に、図７及び図８の薄膜を用いた記録磁極に磁界を媒体対向面方向に印加したときに、その磁区状態がどの様に変化するかについて説明する。

【００２８】図１０は、図７に示すアスペクト比が４：１の薄膜を用いた記録磁極に対して磁界を媒体対向面方向に印加したときの磁区状態を模式的に示している。図＊１１は、図８に示すアスペクト比が６：１の薄膜を用いた記録磁極に対して磁界を媒体対向面方向に印加したときの磁区状態の変化を模式的に示している。

【００２９】図１０に示されるように、アスペクト比が４：１の薄膜を用いた記録磁極では、横方向に磁化が向いている磁区面積が大きいため、磁界を印加したときには、横方向の磁化が媒体対向面方向へと磁化回転することで記録磁極全体の磁化の媒体対向面方向の成分が増えていくのが支配的となる。なお、この場合、媒体対向面方向と逆方向に磁化が向いている磁区面積が小さくなると共に媒体対向面方向と同方向に磁化が向いている磁区面積が大きくなるといった磁壁移動は生じるが、この磁壁移動による磁化の媒体対向面方向成分の増加は、磁化回転に比較してその比率が低く、効果が少ない。

【００３０】これに対して、図１０のアスペクト比が６：１の薄膜を用いた記録磁極では、媒体対向面方向に磁化が向いている磁区面積が大きくなっており、これに対して横方向に磁化が向いている磁区面積がもともと少ない。このため、媒体対向面方向成分の増加は、横方向の磁化が媒体対向面方向へと磁化回転することによる効果よりも、媒体対向面方向とは逆方向に磁化が向いている磁区面積が小さくなると共に媒体対向面方向と同方向に磁化が向いている磁区面積が大きくなる磁壁移動による効果の方が比率が大きい。このため、この磁壁移動が媒体対向面方向成分の増加の支配的要因となる。

【００３１】一般に、磁壁移動よりも磁化回転の方が高速に行われることが知られているため、高周波の磁気記録への応用を考慮した場合、図６及び図１０のアスペクト比４：１の薄膜を用いた記録磁極の方が、図７及び図１１のアスペクト比６：１の薄膜を用いた記録磁極よりも、高周波での磁気記録を行う記録磁極に適した構造を有しているといえる。

【００３２】更に、高周波での磁気記録に適した記録磁極のアスペクト比は、その軟磁性材料の種類や薄膜の厚みによっても異なるが、図７のような最適な磁区状態とするためには、記録磁極の横方向への異方性磁界の大きさＨｋが、記録磁極を一様に横方向に磁化し飽和させたときにその記録磁極の膜内部に生じる静磁界Ｈｄよりも大きい値となれば良い。記録磁極が図７のように短冊状の場合、その膜内部に生じる静磁界Ｈｄは、式１で示される値をとる。（式１）

【００３３】

【数１】

$$Hd = 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right)B$$

【００３４】ここで、記録磁極のポール長をＬｐ、記録トラック幅をＴｗ、厚さをＤｐ、飽和磁束密度をＢとする。

【００３５】従って、記録磁極の異方性磁界Ｈｋが静磁界Ｈｄよりも大きくなれば良いため、記録磁極としては、式２を満たすような形状を有するようにすれば良

い。（式２）

【００３６】

＊【数２】

$$Hk > 8 \arctan\left(\frac{DpLp}{Tw\sqrt{Dp^2 + Tw^2 + Lp^2}}\right)B$$

【００３７】（記録磁極と薄膜導電体との距離）次に、本発明の単磁極ヘッドの記録磁極と薄膜導電体との距離について説明する。

【００３８】図１乃至図６に示す本発明の単磁極ヘッドでは、記録磁極１５がリターンヨーク１１と直接結合しない構造となっているため、記録磁極１５とリターンヨーク１１による磁気回路上の効率がある程度低下する。このため、記録磁極１５に記録に十分な磁化を発生させるためには、薄膜導電体１３の表面に発生する磁界を記録磁極１５にて十分活用する必要がある。すなわち、薄膜導電体１３によって、記録磁極１５全体に一様に磁界を発生させるために、薄膜導電体１３と記録磁極１５との全面を十分に近接配置する必要がある。

【００３９】ここで、薄膜導電体１３に励磁電流Ｉが流れるとき、薄膜導電体１３の周辺に発生する磁界強度Ｈを近似的に計算する。図１及び図２に示すように薄膜導電体１３の励磁電流Ｉ方向（半径方向と同じ）に対する断面の縦の長さをＬｃ（薄膜導電体１３の媒体対向面方向の長さＬｃと同じ）、横の長さ（トラック走行方向の長さ）をＤｃとする。また、薄膜導電体１３の半径方向の長さＷｃが記録磁極１５の記録トラック幅Ｔｗに対して十分長いとする。このとき、薄膜導電体１３に励磁電流Ｉを流すと、薄膜導電体１３から距離ｒだけ離れた位置に発生する磁界Ｈは、近似的には、式３で示される値をとる。

（式３）

Ｈ＝Ｉ／２（Ｌｃ＋Ｄｃ＋２ｒ）

本発明の単磁極ヘッドでは、薄膜導電体１３の半径方向の長さＷｃが記録磁極１５の記録トラック幅Ｔｗよりも十分長いため、薄膜導電体１３から励起される磁界Ｈを記録磁極１５の全体に一様に加えることが可能である。したがって、薄膜導電体１３と記録磁極１５との距離をＲ、薄膜導電体１３に流れる励起電流Ｉの最大値をＩｍａｘとしたとき、記録磁極１５に加わる磁界の最大値Ｈｍａｘは、式４で示される値をとる。

（式４）

Ｈｍａｘ＝Ｉｍａｘ／２（Ｌｃ＋Ｄｃ＋２Ｒ）

よって、記録磁極１５に加える磁界を強くするためには、薄膜導電体１３と記録磁極１５との距離Ｒを短くする必要がある。記録磁極１５内の自発磁化を飽和させるためには、記録磁極１５の異方性磁界Ｈｋ以上の強さの磁界を、記録磁極１５の全体に対して加えることが必要であるため、薄膜導電体１３と記録磁極１５との距離Ｒは、式５を満たす範囲の値をとれば良いこととなる。

（式５）

Ｈｋ＜Ｉｍａｘ／２（Ｌｃ＋Ｄｃ＋２Ｒ）

以上は、記録磁極１５に近接配置する薄膜導電体１３が１層の場合であるが、図３、４のように薄膜導電体を多層化したり、図５、６のように薄膜導電体を記録磁極の両側に配置することも可能である。ここで、記録磁極に近接配置する薄膜導電体の枚数をＮ（Ｎ＞１）とし、また、記録磁極に対して複数の薄膜導電体の距離がそれぞれ略同一値Ｒとなるとすると、記録磁極と複数の薄膜導電体との距離Ｒは、式６を満たす範囲の値をとれば良いこととなる。

（式６）

Ｈｋ＜Ｎ×Ｉｍａｘ／２（Ｌｃ＋Ｄｃ＋２Ｒ）

以上説明したように、図１乃至図６に示す本発明の単磁極ヘッドでは、記録磁極をリターンヨークに直接結合させず、薄膜導電体の媒体対向面方向の長さＬｃよりも記録磁極のポール長Ｌｐを短くすることにより、記録磁極をアスペクト比の値の小さい形状にした。これによって、非記録時の記録磁極の残留磁化による強い漏洩磁界の発生を抑制可能であるため、漏洩磁界の影響による磁気記録媒体の破壊を防止することが可能である。また、アスペクト比の小さい形状とすることで、記録磁極が非記録時から記録時において磁化回転により記録磁極全体の磁化の媒体対向面方向の成分が増えていくのが支配的な特性を有することとなり、高周波での磁気記録に適した単磁極ヘッドを実現することが可能である。

（磁気ディスク装置）次に、本発明の１乃至図６の単磁極ヘッドを用いた垂直磁気記録装置について説明する。

【００４０】図１２に本発明の垂直磁気記録装置の概観図を示している。図１２に示されるように、本発明の垂直磁気記録装置は、上面の開口した矩形箱上の筐体２５と、複数のねじにより筐体２５にねじ止めされる筐体の上端開口を閉塞する図示しないトップカバーとを有している。筐体２５内には、垂直磁気記録媒体２１、この垂直磁気記録媒体２１を支持および回転させる駆動手段としてのスピンドルモータ２０、垂直磁気記録媒体２１に対して情報の記録及び再生を行なう磁気ヘッド２２、磁気ヘッド２２を先端に搭載したサスペンションを有し且つ磁気ヘッド２２を垂直磁気記録媒体２１に対して移動自在に支持するヘッドアクチュエータ２３、ヘッドアクチュエータ２３を回転自在に支持する回転軸２７、回転軸２７を介してヘッドアクチュエータ２３を回動および位置決めするボイスコイルモータ２６、ヘッドアンプ回路２４が収納されている。

【００４１】また、図１３には、本発明の垂直磁気記録

装置の磁気ヘッド２２の拡大図を示してる。図１３において、磁気ヘッド２２は記録部３０と再生部４０とを有している。このうち、記録部３０に本発明の単磁極ヘッドを用いており、この記録部３０は、記録磁極１５、薄膜導電体１３、リターンヨーク１１などから構成されている。記録部３０は、再生部４０と共に浮上スライダ５０に組み込まれており、この浮上スライダ５０が所定速度で回転する垂直磁気記録媒体６０上を極低位置で浮上走行することにより、記録磁極１５及びリターンヨーク１１が、磁気記録媒体６０表面に対して近接対向している。

【００４２】また、垂直磁気記録媒体６０は、本発明の垂直磁気記録装置の情報の記録対象となる垂直磁気記録媒体であり、アルミニウムや強化ガラスなどを用いた基板６１上にパーマロイ、センダスト、ＣｏＺｒＮｂなどを用いた軟磁性裏打ち層６２、ＣｏＣｒ系合金、ＣｏＰｔ系合金などを用いた垂直配向磁気記録層６３、カーボン膜などによる保護層６４、潤滑層６５が順に積層されている。軟磁性裏打ち層６２、垂直配向磁気記録層６３はそれぞれ結晶配向制御などを目的とした下地層を有していても良い。

【００４３】ここで、磁気ヘッド２２の記録部３０と磁気記録媒体６０との構造的位置関係において、磁気記録媒体６０への適切な情報記録を可能とする条件を以下に説明する。

【００４４】磁気記録媒体６０への適切な情報記録を可能とする条件としては、記録磁極１５の先端から磁気記録媒体６０の軟磁性裏打ち層６２までの磁気スペーシングをＳ、記録磁極１５とリターンヨーク１１間の距離をＤとしたとき、磁気スペーシングＳが距離Ｄよりも短いことが必要となる。すなわち、磁気スペーシングＳが距離Ｄよりも短い場合は、記録磁極１５の先端から出た磁束は、垂直配向磁気記録層６３を垂直方向に通過し軟磁性裏打ち層６２を経由してリターンヨーク１１へと戻ることとなり、垂直磁気記録方式として適切な磁束の流れとなる。一方、距離Ｄの方が磁気スペーシングＳよりも短くなってしまった場合は、記録磁極１５の先端から出た磁束がリターンヨーク１１へと流れる方向に集中してしまい、軟磁性裏打ち層６２へは磁束が殆ど流れなくなるため、磁気ヘッド２２の記録部３０と磁気記録媒体６０との構造的位置関係としては不適切である。

【００４５】このように、記録磁極１５の先端から軟磁性裏打ち層６２までの磁気スペーシングＳが記録磁極１５とリターンヨーク１１間の距離Ｄより短くした位置関係にて、情報記録を行なうことにより、良好な垂直磁気記録特性にて情報記録を行なうことができる。

【００４６】

【発明の効果】以上詳述したように本発明では、記録磁極をリターンヨークに直接結合させず、薄膜導電体の媒体対向面方向の長さよりも記録磁極のポール長を短くすることにより、記録磁極をアスペクト比の値の小さい形状にした。これによって、非記録時の記録磁極の残留磁化による強い漏洩磁界の発生を抑制可能であるため、漏洩磁界の影響による垂直磁気記録媒体の破壊を防止することが可能である。また、記録磁極をアスペクト比の小さい形状とすることで、非記録時から記録時において磁化回転により記録磁極全体の磁化の媒体対向面方向の成分が増えていくのが支配的な特性を有した高周波での磁気記録に適した垂直磁気記録ヘッド及び垂直磁気記録装置を実現することが可能である。

【図面の簡単な説明】

【図１】本発明の実施形態に係わる単磁極ヘッドの概略構造図。

【図２】本発明の実施形態に係わる単磁極ヘッドの断面概略図。

【図３】本発明の実施形態に係わる薄膜導電体を複数枚設けた構成の単磁極ヘッドの概略構造図。

【図４】本発明の実施形態に係わる薄膜導電体を複数枚設けた構成の単磁極ヘッドの断面概略図。

【図５】本発明の実施形態に係わる薄膜導電体を記録磁極の両側に設けた構成の単磁極ヘッドの概略構造図。

【図６】本発明の実施形態に係わる薄膜導電体を記録磁極の両側に設けた構成の単磁極ヘッドの断面概略図。

【図７】アスペクト比が４：１の形状の記録磁極の磁区状態を模式的に示した図。

【図８】アスペクト比が６：１の形状の記録磁極の磁区状態を模式的に示した図。

【図９】アスペクト比が２０：１の形状の記録磁極の磁区状態を模式的に示した図。

【図１０】アスペクト比が４：１の形状の記録磁極において磁界を媒体対向面方向へ印加したときの磁区状態を模式的に示した図。

【図１１】アスペクト比が６：１の形状の記録磁極において磁界を媒体対向面方向へ印加したときの磁区状態を模式的に示した図。

【図１２】本発明の実施形態に係わる垂直磁気記録装置の概観図。

【図１３】本発明の実施形態に係わる垂直磁気記録装置の垂直磁気ヘッドと垂直磁気記録媒体との最適な構造的位置関係を説明するための図。

【図１４】比較例１の従来型の薄膜単極ヘッドの概略構造図。

【図１５】比較例２の従来型の薄膜単極ヘッドの概略構造図。

【符号の説明】

１０…基板
１１…リターンヨーク
１２、１４、１６、１８…絶縁層
１３、１７、１９…薄膜導電体
１５…記録磁極

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２０…スピンドルモータ
２１…垂直磁気記録媒体
２２…磁気ヘッド
２３…ヘッドアクチュエータ
２４…ヘッドアンプ回路
２５…筐体
２６…ボイスコイルモータ
２７…回転軸
３０…記録部
４０…再生部
５０…浮上スライダ

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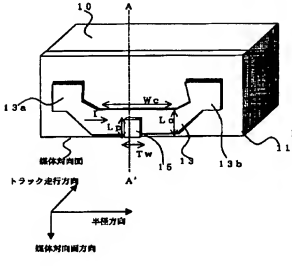
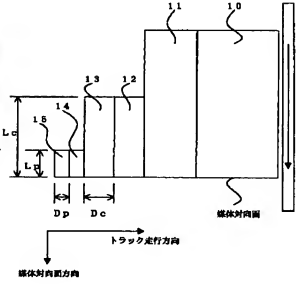
＊６０…垂直磁気記録媒体
６１…基板
６２…軟磁性裏打ち層
６３…垂直配向磁気記録層
６４…保護層
６５…潤滑層
７１、８１…記録磁極
７２、８２…励磁用導電体
７３、８３…リターンヨーク
８４…絞込み位置
＊

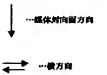
【図１】



【図２】



【図９】



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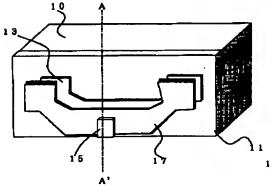

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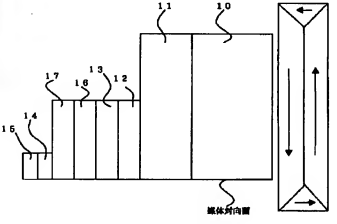
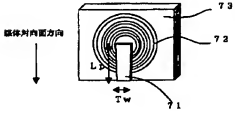


【図８】

【図１４】



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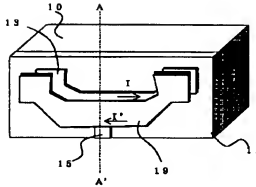

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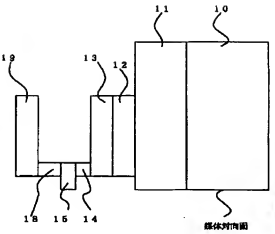

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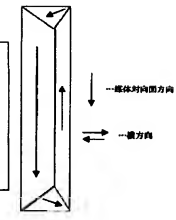

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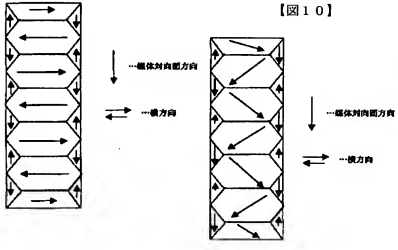
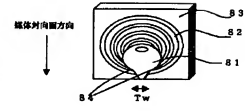


【図１０】

【図１５】



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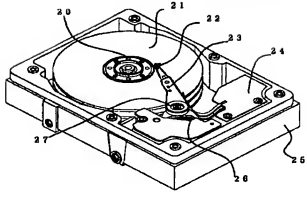

【図１３】